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Landsat

Instruments

Mission Assurance Requirements

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Document Control Information

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Landsat Instruments

Mission Assurance Requirements (MAR)

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DOCUMENT CHANGE RECORD

Note: the Document Change Record will be produced by the LDCM Project configuration management database and will be included in each formal release of this document.

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1 OVERALL REQUIREMENTS

1.1 GENERAL REQUIREMENTS

This document presents the Goddard Space Flight Center (GSFC) LDCM Instrument Safety and Mission Assurance (SMA) requirements. The Contractor shall have an organized SMA program for flight hardware/software and ground support equipment as defined in this document appropriate to the nature of the particular hardware or software to be delivered. The SMA program shall encompass all software critical for mission success and the ground system that interfaces with flight equipment to the extent necessary to ensure the integrity and safety of flight items.

Managers of the assurance activities shall have direct access to Contractor management independent of project management, with the functional freedom and authority to interact with all other elements of the project.

A Quality Manual that provides for control and traceability through all phases of the design, manufacturing, and testing of deliverable items shall be made available for review. If needed, supplemental plans or procedures describing how the requirements of this document will be accomplished shall be developed and made available for project review. The rationale for any planned noncompliance with a requirement shall be submitted to the GSFC LDCM Project for approval.

1.2 USE OF MULTI-MISSION OR PREVIOUSLY DESIGNED, FABRICATED, OR FLOWN HARDWARE

When hardware that was designed, fabricated, or flown on a previous project is considered to have demonstrated compliance with some or all of the requirements of this document, such that certain tasks need not be repeated, the Contractor shall demonstrate how the hardware complies with LDCM requirements.

1.3 SURVEILLANCE OF THE CONTRACTOR

The work activities, operations, and documentation performed by the Contractor or his suppliers are subject to evaluation, review, audit, and inspection by government-designated representatives from the GSFC LDCM Project, the Government Inspection Agency (GIA), or an independent assurance contractor (IAC). In-plant responsibilities and authority to those agencies will be documented via a letter of delegation or contract with the IAC. The quality assurance (QA) representatives shall be provided documents, records, and equipment needed to perform their assurance and safety related surveillance activities, including a suitable in-plant work area (upon request).

1.4 REFERENCE DOCUMENTS

To the extent referenced herein, applicable portions of the documents listed in Appendix A form a part of this document.

1.5 ACRONYMS AND GLOSSARY

Definitions and acronyms are listed in the OLI Acronym List and Lexicon.

2 QUALITY ASSURANCE REQUIREMENTS

2.1 GENERAL REQUIREMENTS

A Quality Management System (QMS) that is compliant with the minimum requirements of ANSI/ISO/ASQ Q9001-2000 (or equivalent) shall be planned, documented, and implemented. International Organization for Standardization (ISO) certification is not mandatory. The Contractor Quality Manual shall be made available for the GSFC LDCM Project review at the Contractor's facility.

2.2 SUPPLEMENTAL QMS REQUIREMENTS

Assurance related requirements not adequately covered by ANSI/ISO/ASQ Q9001-2000 are identified in the following sections.

2.2.1 Control of Nonconforming Product

Nonconforming Product is a condition of any hardware, software, material, or service in which one or more characteristics do not conform to requirements. Nonconforming products fall into two categories--discrepancies and failures.

a. A discrepancy is a departure from specification that is detected during inspection or process control testing, etc., while the hardware or software is not functioning or operating (typically addressed via Material Review Board (MRB) process).
b. A failure is a departure from specification that is discovered in the functioning or operation of the hardware or software (typically addressed via Failure Review Board (FRB) process).

2.2.1.1 Nonconformance Reporting and Corrective Action (NRCA)

The Contractor shall have a system for:

a. Identifying and reporting nonconforming hardware and software through a closed loop reporting system
b. Controlling and segregating nonconforming material from normal production flow
c. Ensuring that positive corrective action is implemented to preclude recurrence
d. Verifying the adequacy of implemented corrective action by audit and test, as appropriate

2.2.1.1.1 <u>Reporting of Discrepancies</u>

A system for documenting and tracking the disposition of all discrepancies shall be implemented. The GSFC LDCM Project shall be provided access to Contractor’s material discrepancy data files applicable to LDCM.

2.2.1.1.2 Reporting of Failures

An electronic database system for documenting and tracking the disposition of all failures shall be implemented. The GSFC LDCM Project shall be a member of the Failure Review Board. The GSFC LDCM Project shall be provided access to Contractor's failure data files applicable to LDCM and FRB meeting schedules and agenda. Failure reporting shall begin with the first "power on application" tests at the component level or the first operation of a mechanical item.

Failure reports shall be submitted to the GSFC LDCM Project office for review. Failures shall be reported within one business day of occurrence. Written reports documenting the failure shall be provided within 5 business days. The Contractor shall submit a list of all open failure reports and a separate list of the failure reports closed during the month.

2.2.2 Control of Monitoring and Measuring Devices

Testing and Calibration Laboratories shall be compliant with the requirements of ANSI/ISO 17025 – General Requirements for the Competence of Testing and Calibration Laboratories.

2.2.3 Configuration Management

The Contractor shall prepare and use a CM System that provides control of changes to hardware, software products and documentation. The CM system shall provide baseline control, configuration identification, configuration control, configuration status accounting, and configuration authentication through reports to and audits by the LDCM Project CMO.

Control of changes to software products shall begin in the testing phase and continue until delivery. Formal Software CM (SCM) control shall be implemented in the development cycle no later than first use with flight hardware. A SCM baseline shall be established after each formal software build.

Any flight or GSE item that is found to be non-compliant with the requirements of the contract SOW or this MAR and is not reworked to be compliant, or is not replaced with a compliant item, shall be presented for disposition via a waiver. Waivers will typically affect mission requirements, system safety, cost, schedule, risk or external interfaces. Waivers shall be submitted to the GSFC LDCM Project office for final approval.

2.2.4 Requirements Flow-Down

The Contractor shall ensure flow-down of this MAR and system technical requirements to all suppliers and establish a process to verify compliance. The contract review and purchasing processes shall indicate the process for documenting, communicating, and reviewing requirements with sub-tier suppliers to ensure requirements are met.

2.2.5 Ground Support Equipment (GSE)

The Contractor shall address safety and mission assurance for GSE. Mechanical and electrical GSE and associated software that directly interfaces with flight deliverable items shall be assembled and maintained to the same standards as the deliverable flight items (reference Sections 10.3.2 and 10.4.3).

2.2.6 Manufacturing, Assembly, and Test Documentation

A traveler system shall be established to plan and document all manufacturing, assembly, and test activities. Traveler steps may reference controlled procedures, processes and associated drawings.

2.3 HANDLING, STORAGE, PRESERVATION, MARKING, LABELING, PACKAGING, PACKING, AND SHIPPING

The Contractor shall prepare and implement procedures for the handling, storage, preservation, marking, labeling, packaging, packing, and shipping of all products. Procedures shall be submitted in accordance with the CDRL.

2.4 GOVERNMENT ACCEPTANCE

Prior to acceptance by the Government, quality assurance personnel shall ensure that deliverable contract end-items, including the Acceptance Data Package and Software Delivery Package, are in accordance with contract requirements. A copy of the data package shall be submitted to the Government in accordance with the CDRL.

3 SYSTEM SAFETY REQUIREMENTS

3.1 GENERAL REQUIREMENTS

The Contractor's system safety program shall be initiated in the concept phase of design and continue throughout all phases of the mission. GSFC Safety Office will certify safety compliance prior to the Pre-Ship Review. The Contractor's system safety program shall accomplish the following:

a. Provides for the early identification and control of hazards to personnel, facilities, support equipment, and the flight system during all stages of project development including design, fabrication, test, transportation and ground activities. The program shall address hazards in the flight hardware, associated software, ground support equipment, operations, and support facilities, and shall conform to the safety review process requirements of NASA-STD-8719.8, "Expendable Launch Vehicle Payloads Safety Review Process Standard".
b. Meets the system safety requirements of EWR 127-1 "Range Safety Requirements Eastern and Western Range" and KHB 1710.2, "Kennedy Space Center Safety Practices Handbook".
c. Meets the baseline industrial safety requirements of the institution, EWR 127-1, applicable Industry Standards to the extent practical to meet NASA and OSHA design and operational needs, and any special contractually imposed mission unique obligations. This should be documented in the contractor's Facility Health and Safety Plan.

3.2 SYSTEM SAFETY PROGRAM PLAN (SSPP)

The Contractor shall prepare a System Safety Program Plan (SSPP) that describes in detail, tasks and activities of system safety management and system safety engineering required to identify, evaluate, eliminate, and control hazards, or reduce the associated risk to a level acceptable throughout the system life cycle. The plan provides a formal basis of understanding between the Contractor and GSFC on how the system safety program will be conducted to meet the requirements of EWR 127-1 and NPR 8715.3, including general and specific provisions. The approved plan shall account for all contractually required tasks and responsibilities on an item-by-item basis and will address roles and responsibilities. The plan should be made available for the Government to review.

3.3 SAFETY ASSESSMENT REPORT

The Contractor shall perform a safety assessment and hazard analysis of the instrument. This safety assessment, which is an input to the Missile System Prelaunch Safety Package, shall identify all safety features of the hardware, software, and system design, as well as procedural related hazards present in the system. It shall include:

a. Safety criteria and methodology used to classify and rank hazards
b. Results of hazard analyses and tests used to identify hazards in the system
c. Hazard reports documenting the results of the safety program efforts
d. List of hazardous materials generated or used in the system
e. Conclusion with a signed statement that all identified hazards have been eliminated or controlled to an acceptable level
f. Recommendations applicable to hazards at the interface of their system
g. List of safety non-compliances and associated rationale for acceptance

This report will be used by the LDCM Project to generate the MSPSP for submittal to the launch range.

3.4 GROUND OPERATIONS PROCEDURES

All ground operations procedures to be used at GSFC facilities, other integration facilities, or the launch site shall be submitted to the GSFC LDCM Project Office. All hazardous instrument operations as well as the procedures to control them shall be identified and highlighted. All launch site procedures shall comply with the launch site and NASA safety regulations.

3.5 SAFETY NONCOMPLIANCE REQUESTS

When a specific safety requirement cannot be met, an associated safety noncompliance request shall be submitted to the GSFC LDCM Project Office that identifies the hazard and shows the rationale for approval of a noncompliance, as defined in the requirements of EWR 127-1.

3.6 SUPPORT FOR SAFETY WORKING GROUP MEETINGS

The Contractor shall provide technical support to the Project for safety working group meetings, Technical Interface Meetings (TIM), and technical reviews.

3.7 ORBITAL DEBRIS ASSESSMENT

The Contractor shall provide information required to produce the assessment consistent with NPD 8710.3, Policy for Limiting Orbital Debris Generation and NSS 1740.14, Guidelines and Assessment Procedures for Limiting Orbital Debris to the LDCM Project.

3.8 SOFTWARE SAFETY

The Contractor shall establish a software safety program to identify and mitigate safety-critical software products. If any software component is identified as safety-critical, the Contractor shall conduct a software safety program on that component in compliance with NASA-STD-8719.13A, “NASA Software Safety Standard".

The software safety program shall ensure that:

a. Safety-related deficiencies in specifications and design are identified and corrected
b. Software design incorporates positive measures to enhance the safety of the system
c. Software safety is included as an agenda item for formal reviews

The software safety process shall include the following activities:

a. Determination of the safety criticality for each software component
b. Analysis of the consistency, completeness, correctness, and testability of safety requirements
c. Analysis of design and code as required to ensure implementation of safety-critical requirements
d. Analysis of changes for safety impact

4 RELIABILITY REQUIREMENTS

4.1 GENERAL REQUIREMENTS

The Contractor shall develop and implement a reliability program applicable to the development of all software and hardware products and processes. The reliability program shall :

a. Demonstrate that redundant functions, including alternative paths and work-arounds, are independent to the extent practicable.
b. Demonstrate that the stress applied to parts is not excessive.
c. Identify single failure items/points, their effect on the attainment of mission objectives, and possible safety degradation.
d. Show that the reliability design aligns with mission design life and is consistent among the systems, subsystems, and components.
e. Identify limited-life items and ensure that special precautions are taken to conserve their useful life for on-orbit operations.
f. Select significant engineering parameters for the performance of trend analysis to identify performance trends during pre-launch activities.
g. Ensure that the design permits easy replacement of parts and components and that redundant paths are easily monitored.

4.2 RELIABILITY PLAN

The Contractor shall develop, implement, and maintain a Reliability Program Plan . The plan shall address the approach for the reliability activities and associated risk management functions, identify the reliability tasks to be performed, describe how reliability assessments will be integrated with the design, and discuss the scheduling of these tasks relative to the LDCM Project milestones.

The Reliability Program Plan shall be made available at the Contractor's facility for the LDCM Project review.

4.3 PROBABILISTIC RISK ASSESSMENT

The Contractor shall provide the information necessary for the Government to perform comparative numerical reliability assessments and/or predictions to:

a. Evaluate alternative design concepts, redundancy and cross-strapping approaches, and part substitutions

b. Identify the elements of the design which are the greatest detractors of system reliability
c. Identify those potential mission limiting elements and components that will require special attention in part selection, testing, environmental isolation, and/or special operations
d. Assist in evaluating the ability of the design to achieve the mission life requirement and other reliability goals and requirements as applicable
e. Evaluate the impact of proposed engineering change and waiver requests on reliability

4.4 RELIABILITY ANALYSES

The Contractor shall perform reliability analyses concurrently with the design so that identified problem areas can be addressed and corrective action taken (if required) in a timely manner.

4.4.1 Failure Modes and Effects Analysis and Critical Items List

The Contractor shall perform a Failure Modes and Effects Analysis (FMEA) early in the design phase to identify system design problems and associated critical items list (CIL) . As additional design information becomes available, the FMEA shall be refined.

Failure modes shall be assessed at the component interface level. Each failure mode shall be assessed for the effect at that level of analysis, the next higher level, and upward. The failure mode shall be assigned a severity category based on the most severe effect caused by a failure. Mission phases (launch, deployment, on-orbit operation) shall be addressed in the analysis.

Severity categories shall be determined in accordance with Table 4-1:

FMEA analysis procedures and documentation shall be performed in accordance with documented procedures. Failure modes resulting in Severity Categories 1, 1R, 1S or 2 shall be analyzed at a greater depth, to the single parts if necessary, to identify the cause of failure.

Results of the FMEA shall be used to evaluate the design relative to requirements (e.g., no single subsystem failure will prevent removal of power from the subsystem). Identified discrepancies shall be evaluated by management and design groups for assessment of the need for corrective action.

The FMEA shall analyze redundancies to ensure that redundant paths are isolated or protected such that any single failure that causes the loss of a functional path will not affect the other functional path(s) or the capability to switch operation to that redundant path.

Table 4-1
Severity Categories

Category	Severity	Description
1	Catastrophic	Failure modes that could result in serious injury, loss of life (flight or ground personnel), or loss of launch vehicle.
1R		Failure modes of identical or equivalent redundant hardware items that could result in category 1 effects if all failed.
1S		Failure in a safety or hazard monitoring system that could cause the system to fail to detect a hazardous condition or fail to operate during such condition and lead to Severity Category 1 consequences.
2	Critical	Failure modes that could result in loss of one or more mission objectives as defined by the GSFC project office.
2R		Failure modes of identical or equivalent redundant hardware items that could result in Category 2 effects if all failed.
3	Significant	Failure modes that could cause degradation to mission objectives.
4	Minor	Failure modes that could result in insignificant or no loss to mission objectives

All failure modes that are assigned to Severity Categories 1, 1R, 1S, and 2, shall be itemized on a Critical Items List (CIL) and maintained with the FMEA report. Rationale for retaining the items shall be included on the CIL. The FMEA and CIL shall be maintained at the Contractor's facility for GSFC LDCM Project review and/or audit. Results of the FMEA and the CIL shall be presented at all design reviews starting with the PDR. The presentations shall include comments on how the analysis was used to perform design trade-offs or how the results were taken into consideration when making design or risk management decisions.

4.4.2 Fault Tree Analysis

The Contractor shall perform Fault Tree Analyses (FTAs) that address both mission failures and degraded modes of operation. FTAs shall be retained for LDCM Project review upon request. Beginning with each undesired state (mission failure or degraded mission), the fault tree shall be expanded to include all credible combinations of events/faults and environments that could lead to that undesired state. Component hardware/software failures, external hardware/software failures, and human factors shall be considered in the analysis. The fault tree itself is not a quantitative model, but becomes a quantitative assessment when combined with quantitative data as part of the PRA.

4.4.3 Parts Stress Analyses

The Contractor shall perform stress analyses on Electrical, Electronic, and Electromechanical (EEE) parts and devices, as applied in circuits within each component for conformance with the de-rating policy of the GSFC Preferred Parts List (PPL-21). The analyses shall be performed at the most stressful part-level parameter values that can result from the specified performance and environmental requirements on the assembly or component. The analyses shall be performed in close coordination with the packaging reviews and shall be required input data for component-level design reviews. The analyses shall be documented and maintained at the Contractor's facility for the GSFC LDCM Project review.

4.4.4 Worst-Case Analyses

The Contractor shall perform worst-case analyses for critical parameters that are subject to variations that could degrade performance, where failure results in a severity category of 2 or higher, and provides data that question the flightworthiness of the design (refer to Table 4-1). Analyses or test or both shall demonstrate adequacy of margins in the design of electronic circuits, optics, electromechanical and mechanical items (mechanisms). The analyses shall consider all parameters set at worst-case limits and worst-case environmental stresses for the parameter or operation being evaluated. The analyses shall be updated in keeping with design changes. The analyses and updates shall be presented at applicable design reviews.

4.4.5 Software Reliability

The Contractor shall implement a software reliability program addressing the tolerance of minor defects and the complete removal of critical defects. The software reliability program shall monitor and control defect removal, field performance, and include a model to predict the bug removal rate or number of bugs remaining based on testing, running time, or bug count. The software reliability model may be:

a. Time domain (related to the number of bugs at a given time during development)
b. Data domain (estimated by running the program for a subset of input data)
c. Axiomatic (based on laws/rules applied during the programming process)
d. Based other methods resulting from input data sets, logic paths, etc.

The Contractor shall document actions to verify that the software design and software engineering techniques improve the duration or probability of failure free performance and ensure repeatability of the software.

4.4.6 Reliability Block Diagram

The Contractor shall develop a Reliability Block Diagram that address both mission failures and degraded modes of operation. Reliability block diagram (RBD) analyses shall be used to (1)quantify system reliability and function; (2)assess the level of failure tolerance achieved (redundancy);(3)identify intersystem disconnects as well as areas of incomplete design definition, and (4)perform trade-off studies to optimize reliability and cost. For the initial assessments, the contractor shall use the parts count reliability prediction methodology of MIL-HDBK-217. As the design matures, a complete RBD, failure definitions, and mathematical models shall be developed in accordance with MIL-HDBK-217.

4.5 RELIABILITY ANALYSIS OF TEST DATA

Information acquired during the normal test program shall be fully utilized to assess flight equipment reliability performance and identify potential or existing problem areas.

4.5.1 Trend Analyses

Trend analyses shall be performed to the component level to track measurable parameters that relate to performance stability. Selected parameters shall be monitored for trends starting at component acceptance testing and continuing during the system integration and test phases. The monitoring shall be accomplished within the normal test framework (i.e., during functional tests, environmental tests, etc). The reliability trending program shall be merged with the performance trending program in accordance eith the CDRL. A system shall be established for tracking total operational time and recording and analyzing the parameters, as well as any changes from the first observed value, even if the levels are within specified limits. The Contractor shall deliver a list of parameters to be monitored and the trend analysis reports.Trend analysis data shall be reviewed with the mission operational personnel prior to launch. Analysis of Test Results

Test information, trend data, and failure investigations shall be analyzed to evaluate reliability implications. Identified problem areas shall be documented and directed to the attention of project management for action. This information shall be included in status reports to the GSFC LDCM Project or it may be a separate monthly report. The results of the analyses shall be presented at design reviews. The presentations shall include comments on how the analysis was used to perform design trade-offs or how the results were taken into consideration when making design or risk management decisions.

4.6 LIMITED-LIFE ITEMS

The Contractor shall prepare and implement a Limited-Life Plan to identify and manage limited-life items. The Limited-Life Plan may be combined with the Reliability Plan and/or the Risk Management Plan, or maintained as a separate document. Limited-life items include all hardware that is subject to degradation because of age, operating time, or cycles such that their expected useful life is less than twice the required life when fabrication, test, storage, and mission operation are combined. Any items to be used for which the expected life is less than the mission design life shall be approved by the GSFC LDCM Project via a waiver.

The Contractor shall maintain a list of limited-life items , which shall include the following data elements: item, expected life, required life, duty cycle, rationale for selection and effect on mission parameters. An item's useful life period begins with fabrication and ends when the orbital mission is completed.

Records shall be maintained that allow evaluation of the cumulative stress (time and/or cycles) for limited-life items, starting when useful life is initiated and indicating the project activity that stresses the items. Refer to GEVS Section 2.3.5 and 2.4.5.1 for guidance.

4.7 CONTROL OF SUBCONTRACTORS AND SUPPLIERS

The Contractor shall assure that system elements obtained from subcontractors and suppliers meet the project reliability requirements. All subcontracts shall include provisions for review and evaluation of the subcontractor and supplier reliability efforts.

Reliability requirements shall be tailored in hardware and software subcontracts for the project and shall exercise necessary surveillance to ensure that subcontractor and supplier reliability efforts are consistent with overall system requirements. As a result of this tailoring, the Contractor shall:

- Incorporate quantitative reliability requirements in subcontracted equipment specifications
- Ensure that subcontractors have reliability programs that are compatible with the overall program
- Review subcontractor assessments and analyses for accuracy and correctness of approach
- Review subcontractor test plans, procedures, and reports for correctness of approach and test details
- Attend and participate in subcontractor design reviews
- Ensure that subcontractors comply with the applicable system reliability requirements during the project operational phase

5 SOFTWARE ASSURANCE REQUIREMENTS

5.1 GENERAL REQUIREMENTS

The Contractor shall prepare a Software Development and Management Plan (SDMP) that addresses software development and software assurance functions in compliance with ANSI/ISO/ASQ 9001-2000, or equivalent . The SDMP shall be applied to software and firmware developed for the LDCM Project.

5.2 SOFTWARE TECHNICAL REVIEWS

A program of software engineering working-level peer reviews shall be implemented throughout the development life cycle to identify and resolve concerns prior to formal system level reviews. Topics that shall be addressed in the peer reviews include:

1. Design verification
2. Coding
3. Analyses and studies
4. Safety
5. Risk assessment, resolution and contingency plans
6. Procurements
7. Configuration management
8. Testability and test planning (including test anomalies and resolution)

Software systems reviews shall be integrated with the major technical review program.

Topics to be addressed At PDR:

1. Software documentation in compliance with the Configuration Management Plan
2. Software, both instrument-based, GSE-based, and external, necessary to operate, test, calibrate, design, and analyze the instrument
3. Compatibility of instrument software with the spacecraft (S/C), and for operation and calibration through the ground data information system for the bridge mission and Interface Data Processing Segment (IDPS) Total System Performance Responsibility (TSPR) contractor for NPOESS.
4. Software necessary to analyze instrument test data and for in-flight engineering analysis
5. Software capability to provide all instrument operational modes
6. Software required for operations analyses utilizing the System Test Equipment (STE)

7. Software for supporting instrument verification, integration, monitoring of performance, ground operations, as well as supporting evaluation of data acquired during S/C integration and flight operations
8. Providing and maintaining real-time and off-line software for instrument calibration
9. Calibration in all channels
10. Software for a formatted real-time data dump
11. Software test plan

At CDR The Contractor shall provide updates of items required for SWPDR and definition of the test procedures and test cases to be used with each type of testing (unit, integration, and acceptance).

5.3 SOFTWARE QUALITY ASSURANCE (SQA)

The Contractor shall provide, as part of the SDMP, an SQA plan that describes how the software quality assurance activities will be planned, implemented, and documented. The SQA program shall:

1. Ensure that assurance requirements are documented and satisfied throughout all phases of the development life cycle
2. Detect actual or potential conditions that could degrade quality, including deficiencies and system incompatibilities, and provide a process to ensure corrective action is taken and completed
3. Ensure timely and effective preventive action by identifying root causes of deficiencies and nonconformance
4. Ensure standards and procedures for management, engineering and assurance activities are specified and compliance by management and engineering personnel is verified

5.4 SOFTWARE VERIFICATION AND VALIDATION

The Contractor shall prepare and maintain a Software Performance Verification Matrix as a part of the System Performance Verification Matrix that shows the flow-down of each software system performance requirement and the verification process (refer to Section 9.2.1.1).V&V activities shall be performed during each phase of the software life cycle and shall include the following:

1. Analysis of system and software requirements allocation, verifiability, testability, completeness, and consistency (including analysis of test requirements)

2. Design and code analysis including design completeness and correctness
3. Interface analysis (requirements and design levels)
4. Formal Inspections
5. Formal Reviews (phase transition reviews)
6. Test planning, performance, and reporting

Access to information shall be provided when requested by the GSFC LDCM Project for the NASA Independent Verification and Validation (IV&V) effort. Electronic access to the information shall be permitted.

5.5 SAFETY ASSURANCE

If any component is identified as safety critical, the Contractor shall conduct a software safety program on that component that complies with NASA-STD-8719.13A “NASA Software Safety Standard". Refer to Section 3.10 for additional software safety requirements.

5.6 GFE, EXISTING AND PURCHASED SOFTWARE/FIRMWARE (SW/FW)

If the Contractor is provided SW/FW as government-furnished equipment (GFE), or will use existing or purchased SW/FW; the Contractor shall ensure that the SW/FW meets the functional, performance, and interface requirements placed upon it. This SW/FW shall meet all applicable standards, including those for design, code, and documentation; or a waiver to those standards shall be submitted for GSFC LDCM Project approval. Any significant modification to any piece of the existing SW/FW shall be subject to all of the provisions of the Contractor’s SQA plan and the provisions of this MAR. The definition of a significant modification is a change of 20% of the source lines of code in the SW/FW.

6 PARTS REQUIREMENTS

6.1 GENERAL REQUIREMENTS

The Contractor shall plan and implement an Electrical, Electronic, and Electromechanical (EEE) Parts Control to ensure that all parts selected for use in flight hardware meet mission objectives for quality and reliability for a Quality Level 2 Mission.

The Contractor shall prepare a Parts Control Plan (PCP) describing the approach and methodology for implementing the Parts Control Program. The PCP shall define the criteria for parts selection and approval based on the guidelines in this chapter. The PCP shall be made available for the LDCM Project review at the Contractor's facility.

6.2 ELECTRICAL, ELECTRONIC, AND ELECTROMECHANICAL (EEE) PARTS

The NASA Parts Selection List (NPSL) has been developed to serve as a parts selection tool for design engineers and parts engineers supporting NASA space flight programs. The NPSL provides a detailed listing of EEE part types which the NASA EEE Parts Assurance Group (NEPAG) recommends for NASA flight projects based on evaluations, risk assessments and quality levels. In general, the parts listed in the NPSL:

- Have established procurement specifications
- Have available source(s) of supply
- Are capable of meeting a wide range of application needs
- Have been assessed for quality, reliability, and risk and found to meet the criteria for listing

Custom or advanced technology devices such as custom hybrid microcircuits, detectors, Application Specific Integrated Circuits (ASIC), and Multi-Chip Modules (MCM) shall also be subject to parts control appropriate for the individual technology.

6.2.1 Quality Level

The parts reliability requirement is Quality Level 2. This was determined in accordance with EEE-INST-002. This document provides detailed instructions for the selection and testing of electronic parts to be used in GSFC space flight programs depending on mission requirements. The NPSL may be used as a vehicle for parts selection to the specified quality levels.

6.2.2 Parts Control Board

The Contractor shall establish a Parts Control Board (PCB). The PCB shall manage and control usage of EEE parts for the LDCM project. The PCB shall approve all parts to be used to ensure that the mission requirements have been met. The PCB shall meet regularly to concur, resolve, and document any issues necessary for compliance. The PCB shall be responsible for developing and maintaining a LDCM Project Approved Parts List (PAPL) including responsibility for all parts activities such as failure investigations, disposition of non-conformances, and problem resolutions.

The PCB operating procedures shall be included as part of the PCP. The GSFC LDCM Project parts engineer shall be a voting member of all LDCM PCBs. Meeting minutes or records shall be maintained to document all decisions made and a copy provided to the GSFC LDCM Project Systems Assurance Manager (SAM) within five working days of convening the meeting. These minutes shall be placed into the project parts database. The project SAM retains the right to overturn decisions involving nonconformance within ten days after receipt of meeting minutes.

6.2.3 Parts Selection and Processing

The Contractor shall select an process all parts in accordance with the EEE-INST-002 "Instructions for EEE Parts Selection, Screening, Qualification and Derating". All application notes in EEE-INST-002 shall apply. Parts shall be procured to Quality Level 2 as defined in EEE-INST-002 unless otherwise justified and approved by the PCB in accordance with the reliability program. These requirements shall then become the established criteria for parts selection, testing, and approval for the duration of the project, and shall be documented in the PCP. Parts selected from the NASA Parts Selection List and the GSFC Preferred Parts List (PPL-21) are considered to have met all criteria of EEE-INST-002 for the appropriate parts quality level, and may be approved by the PCB provided all mission application requirements (performance, de-rating, radiation, etc.) are met. If the parts to be used on the Engineering Models are procured by methods 1 through 4 of EEE-INST-002, full paperwork and documentation (i.e. pedigree) are not required.

6.2.3.1 Custom Devices

In addition to applicable requirements of EEE-INST-002, custom microcircuits, hybrid microcircuits, MCM, ASIC, etc. planned for use shall be subjected to a design review. The review may be conducted as part of the PCB activity. The design review shall address, at a minimum, de-rating of elements, method used to assure each element reliability, assembly process and materials, and method for assuring adequate thermal matching of materials.

6.2.4 De-rating

All EEE parts shall be used in accordance with the de-rating guidelines of the GSFC Preferred Parts List (PPL-21). The Contractor's de-rating policy may be used in place of the GSFC Preferred Parts List guidelines and shall be submitted with the PCP. Documentation on parts de-rating analyses shall be maintained and available for GSFC LDCM Project review.

6.2.5 Radiation Hardness

All parts shall be selected to meet their intended application in the predicted mission radiation environment. The radiation environment consists of two separate effects, those of total ionizing dose and single-event effects. Analyses for each part with respect to both effects shall be documented. The possibility of displacement damage shall also be considered for parts susceptible to these effects.

6.2.6 Verification Testing

Verification of screening or qualification tests by re-testing is not required unless deemed necessary as indicated by failure history, Government-Industry Data Exchange Program (GIDEP) Alerts, or other reliability concerns. If required, testing shall be in accordance with EEE-INST-002 as determined by the PCB. The Contractor, however, shall be responsible for the performance of supplier audits, surveys, source inspections, witnessing of tests, and/or data review to verify conformance to established requirements.

6.2.7 Destructive Physical Analysis (DPA)

A Destructive Physical analysis (DPA) shall be required for a sample of components identified based on failure history, construction concerns, vendor information, recent GIDEP alerts or advisories, or other reliability concerns. The DPA should be performed upon receipt of parts or prior to kitting.

A sample of each lot date code of microcircuits, hybrid microcircuits, and semiconductor devices shall be subjected to a DPA. DPA tests, procedures, sample size and criteria shall be as specified in GSFC specification S-311-M-70, Destructive Physical Analysis. Contractor's procedures for DPA may be used in place of S-311-M-70 and shall be submitted with the PCP. Variation to the DPA sample size requirements, due to part complexity, availability, or cost, shall be determined and approved by the PCB on a case-by-case basis. In lieu of performing the required DPAs, the Contractor may provide the required number of DPA samples to GSFC for DPA. This shall be accomplished on a case-by-case basis through mutual agreement by the Contractor and GSFC.

6.2.8 Failure Analysis

Failure analyses shall be performed by experienced personnel and shall support the nonconformance reporting system. The failure analysis laboratory (in-house or out-of-house) shall be equipped to analyze parts to the extent necessary to ensure an understanding of the failure mode and cause. The failure analyses shall be available to GSFC LDCM Project for review upon request.

6.2.9 Parts Age Control

The Contractor shall develop a parts age control process. Prior to use, the PCB shall determine the required additional screening or lot sample testing based on the part type, complexity, expected failure mechanisms, and available data.

Parts drawn from controlled storage after 5 years from the date of the last full screen shall be subjected to a full 100 percent re-screen and sample DPA. Alternative test plans may be used as determined and approved by the PCB on a case-by-case basis. Parts over 10 years from the date of the last full screen or stored in other than controlled conditions where they are exposed to the elements or sources of contamination shall be submitted to the PCB for approval prior to use.

6.3 PARTS LISTS

The Contractor shall create and maintain a Project Approved Parts List (PAPL) and/or a Parts Identification List (PIL) for the duration of the contract . The PAPL and PIL may be incorporated into one list, which shall be submitted to GSFC LDCM Project as a PIL, provided clear distinctions are made as to parts approval status and whether parts are planned for use in flight hardware.

6.3.1 Project Approved Parts List

The PAPL shall be the only source of approved parts for project flight hardware, but may contain parts not actually in flight designs. Only parts that have been evaluated and approved by the PCB shall be listed in the PAPL. Parts must be approved for listing on the PAPL before initiation of procurement activity. The criteria for PAPL listing shall be based on EEE-INST-002 and as specified herein. The PCB will ensure standardization and the maximum use of parts listed in the PAPL. The PAPL and all subsequent revisions shall be available for GSFC LDCM Project review upon request.

6.3.2 Parts Identification List

As opposed to the PAPL, the PIL shall list all parts planned for use in flight hardware regardless of their approval status. The initial PIL and subsequent updates shall be submitted to GSFC in accordance with the contract delivery requirements. The Contractor shall provide the process as to how the PIL will be shared with GSFC’s parts organizations.

6.3.3 As-Built Parts List

In addition to the PAPL and PIL, an ABPL shall be prepared and submitted to GSFC in accordance with the contract delivery requirements. The ABPL identifies parts actually used in flight hardware with additional as-built information, such as parts manufacturers, lot date code and locations (circuit designations) where the parts are used in the hardware.

6.3.4 Parts List Information

Each parts list shall be a composite of the parts selections for each circuit design in the component, including EEE parts. As a minimum, each list shall contain the following information:

a. Part number
b. Description
c. Next assembly
d. Trace ID
e. Quantity issued/used
f. Serial Number
g. Order Type
h. P.O. Number
i. Name or Commercial and Government Entity (CAGE) Code of the part manufacturer
j. Manufacturing lot date code
k. Vendor ID
l. System used
m. Part specification control drawing number
n. Common designator or generic number
o. Drawing number of component to which the list pertains

6.4 GIDEP ALERTS AND PROBLEM ADVISORIES

The Contractor shall participate in the Government/Industry Data Exchange Program (GIDEP). Copies of documentation relevant to the LDCM hardware that are sent to GIDEP shall be provided to the GSFC LDCM Project SAM.

The Contractor shall review and disposition all GIDEP Alerts and Problem Advisories for impact on flight equipment. New parts procurements and parts pulled from storage shall be continuously checked for impact. Parts pulled from inventory for flight shall have the alert history checked for the period dating back to the date code marked on the parts. In addition, the Contractor shall review and disposition any NASA Alerts and Advisories. Alert applicability, impact, and corrective actions shall be documented and status provided to the GSFC LDCM Project on a monthly basis. In the event of a conflict between GIDEP alerts and NASA Advisories, the NASA Advisory shall govern.

Sufficient records shall be maintained to determine applicability of any GIDEP alerts related to parts and materials selected or used for LDCM.

7 MATERIALS, PROCESSES, AND LUBRICATION REQUIREMENTS

7.1 GENERAL REQUIREMENTS

The Contractor shall plan and implement a comprehensive Materials and Processes Control Program (M&PCP) beginning at the design stage of the hardware to help ensure the success and safety of the LDCM mission by the appropriate selection, processing, inspection, and testing of the materials and lubricants for use in flight hardware. The M&PCP Plan shall be made available for the LDCM Project review at Contractor's facility. The GSFC LDCM Project Materials Assurance Engineer (MAE) review and approval is required for each material and lubrication usage or application in LDCM flight hardware.

7.2 MATERIALS SELECTION REQUIREMENTS

In order to anticipate and minimize materials problems during space hardware development and operation, the Contractor shall, when selecting materials and lubricants, consider potential problem areas such as radiation effects, thermal cycling, stress corrosion cracking, galvanic corrosion, hydrogen embrittlement, lubrication, contamination, composite materials, atomic oxygen, useful life, vacuum outgassing, toxic offgassing, flammability and fracture toughness, as well as the properties required by each material usage or application.

7.2.1 Material Identification List (MIL)

The Contractor shall maintain a Materials Identification List (MIL) of all materials planned for use in flight hardware, regardless of their approval status . An As-Built Materials List (ABML) shall also be prepared and submitted to GSFC LDCM Project in accordance with the contract delivery requirements. The ABML identifies materials and lubricants actually used in flight hardware with additional as-built information such as materials manufacturers and lot date codes.

The MIL shall include a Polymeric Materials and Composites Usage List, an Inorganic Materials and Composites Usage List, a Lubrication Usage List, and a Materials Process Utilization List.

7.2.2 Compliant Materials

Compliant materials shall be used in the fabrication of flight hardware to the extent practicable. In order to be compliant, a material must be used in a conventional application and meet the applicable selection criteria identified in Table 7.1. A compliant material does not require a Materials Usage Agreement (MUA).

Table 7-1
Material Selection Criteria

Type Launch	Payload Location	Flammability and Toxic Offgassing	Vacuum Outgassing	Stress Corrosion Cracking (SCC)
ELV	All	Note 1	Note 2	Note 3

NOTES:
1. Hazardous materials requirements, including flammability, toxicity and compatibility as specified in Eastern and Western Range 127-1 Range Safety Requirements, Sections 3.10 and 3.12.
2. Vacuum Outgassing requirements as defined in Section 7.2.6.2.
3. Stress corrosion cracking requirements as defined in MSFC-SPEC-522.

7.2.3 Non-compliant Materials

A material that does not meet the requirements of the applicable selection criteria of Table 7.1, or meets the requirements of Table 7.1 but is used in an unconventional application, shall be considered to be a non-compliant material. The proposed use of a non-compliant material requires that a Materials Usage Agreement (Figure 7-1) and/or a Stress Corrosion Evaluation Form (Figure 7-2) or Contractor's equivalent form, be submitted for review and approval by the GSFC LDCM Project MAE.

7.2.3.1 Materials Used in “Off-the-Shelf-Hardware”

"Off-the-shelf hardware" for which a detailed materials list is not available and where the included materials cannot be easily identified and/or changed shall be treated as non-compliant. A MUA shall be prepared and submitted to define what measures will be used to ensure that all materials in the hardware are acceptable for use. Such measures might include any one, or a combination, of the following: hermetic sealing, vacuum bake-out, material changes for known non-compliant materials, etc. When a vacuum bake-out is the selected method, it shall incorporate a quartz crystal microbalance (QCM) and cold finger to enable a determination of the duration and effectiveness of the bake-out as well as compliance with the LDCM Project contamination plan and error budget.

7.2.4 Conventional Applications

Conventional applications or usage of materials is the use of compliant materials in a manner for which there is extensive satisfactory aerospace heritage.

7.2.5 Non-conventional Applications

The proposed use of a compliant material for an application for which there is limited satisfactory aerospace usage shall be considered a non-conventional application. In that case, the material usage shall be verified for the desired application on the basis of test, similarity, analyses, inspection, existing data, or a combination of those methods.

7.2.6 Polymeric Materials

A polymeric materials and composites usage list (Figure 7-3), or equivalent, shall be prepared and submitted as a part of the MIL for MAE review and approval. Material acceptability shall be determined on the basis of flammability, toxic offgassing, vacuum outgassing, and all other materials properties relative to the application requirements and usage environment.

7.2.6.1 Flammability and Toxic Offgassing

Material flammability and toxic offgassing shall be determined in accordance with the test methods described in NASA-STD-6001. ELV payload materials shall meet the requirements of Eastern and Western Range 127-1 Range Safety Requirements, Sections 3.10 and 3.12.

7.2.6.2 Vacuum Outgassing

Material vacuum outgassing shall be determined in accordance with ASTM E-595. In general, a material is qualified on a product-by-product basis. However, the GSFC LDCM Project may require lot testing of any material for which lot variation is suspected. In such cases, material approval is contingent upon the lot testing results. Only materials have a total mass loss (TML) less than 1.00% and a collected volatile condensable mass (CVCM) less than 0.10% shall be approved for use in a vacuum environment unless application considerations listed on a MUA dictate otherwise.

7.2.6.3 Shelf-Life-Controlled Materials

Polymeric materials that have a limited shelf-life shall be controlled by a process that identifies the start date (manufacturer's processing, shipment date, or date of receipt, etc.), the storage conditions associated with a specified shelf-life, and expiration date. Materials such as o-rings, rubber seals, tape, uncured polymers, lubricated bearings and paints shall be included. The use of materials with expired date code requires a demonstration, by means of appropriate tests, that the properties of the materials have not been compromised for their intended use. Such materials shall be approved by the M&PCB prior to use. When a limited-life piece part is installed in a subassembly, the subassembly item shall be included in the Limited-Life Items List (refer to Section 4.6).

7.2.7 Inorganic Materials

An inorganic materials and composites usage list (Figure 7-4), or equivalent, shall be prepared and submitted as a part of the MIL for MAE review and approval prior to use. In addition, the Contractor may be requested to submit supporting applications data. The criteria specified in MSFC-SPEC-522 shall be used to determine that metallic materials meet the stress corrosion cracking (SCC) criteria. An MUA (Figure 7-1) and SCC evaluation (Figure 7-2) shall be submitted for GSFC LDCM Project MAE review and approval for each material usage that does not comply with the MSFC-SPEC-522 SCC requirements.

7.2.7.1 Fasteners

The Contractor shall comply with the procurement documentation and test requirements for flight hardware and critical ground support equipment fasteners outlined in 541-PG-8072.1.2, Goddard Space Flight Center Fastener Integrity Requirements (formerly GSFC S-313-100). For a copy of 541-PG-8072.1.2, use the following hyperlink --- http://gdms.gsfc.nasa.gov/gdms/plsql/masterlist.menu. Material test reports for fastener lots shall be submitted to the GSFC LDCM Project MAE for review upon request.

Fasteners made of plain carbon or low alloy steel shall be protected from corrosion. When plating is specified, it shall be compatible with the space environment. On steels harder than RC 33, plating shall be applied by a process that is not embrittling to the steel.

7.2.8 Lubrication

A lubrication usage list (Figure 7.5), or equivalent, shall be prepared and submitted as a part of the MIL for MAE review and approval. Also, supporting applications data shall be submitted, upon request.

Lubricants shall be selected for use with materials on the basis of valid test results that confirm the suitability of the composition and the performance characteristics for each specific application, including compatibility with the anticipated environment and contamination effects.

All lubricated mechanisms shall be qualified by life testing; or heritage of an identical mechanism used in identical applications. Evidence of qualification must be provided for GSFC LDCM Project MAE review.

7.3 PROCESS SELECTION REQUIREMENTS

The Contractor shall prepare and submit a material process utilization list (Figure 7-6), or equivalent, as a part of the MIL for MAE review and approval. A copy of any process shall be submitted to the MAE for review upon request. Manufacturing processes (e.g., lubrication, heat treatment, welding, and chemical or metallic coatings) shall be carefully selected to prevent any unacceptable material property changes that could cause adverse effects of materials applications.

7.4 PROCUREMENT REQUIREMENTS

7.4.1 Purchased Raw Materials

The results of nondestructive chemical and physical tests; or a Certificate of Compliance (COC) shall accompany raw materials. This information need only be provided to the GSFC LDCM Project when there is a direct question concerning the material's flightworthiness.

7.4.2 Raw Materials Used in Purchased Products

The Contractor shall require that their suppliers meet the requirements of Section 7.4.1 of this document and provide copies of the results of acceptance tests and analyses performed on raw material; or the Certificates of Compliance (COCs), upon request of the GSFC LDCM Project.

<table>
<tr><td colspan="3">MATERIAL USAGE AGREEMENT</td><td colspan="5">USAGE AGREEMENT NO.:</td><td colspan="3">PAGE OF</td></tr>
<tr><td colspan="2">PROJECT:</td><td>SUBSYSTEM:</td><td colspan="5">ORIGINATOR:</td><td colspan="3">ORGANIZATION:</td></tr>
<tr><td colspan="2">DETAIL DRAWING</td><td colspan="2">NOMENCLATURE</td><td colspan="3">USING ASSEMBLY</td><td colspan="4">NOMENCLATURE</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="3"></td><td colspan="4"></td></tr>
<tr><td colspan="5">MATERIAL & SPECIFICATION</td><td colspan="6">MANUFACTURER & TRADE NAME</td></tr>
<tr><td colspan="5"></td><td colspan="6"></td></tr>
<tr><td rowspan="2">USAGE</td><td rowspan="2">THICKNESS</td><td rowspan="2">WEIGHT</td><td rowspan="2">EXPOSED AREA</td><td colspan="7">ENVIRONMENT</td></tr>
<tr><td colspan="2">PRESSURE</td><td colspan="3">TEMPERATURE</td><td colspan="2">MEDIA</td></tr>
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<tr><td colspan="11">APPLICATION:</td></tr>
<tr><td colspan="11">RATIONALE:</td></tr>
</table>

ORIGINATOR:	PROJECT MANAGER:	DATE:

Figure 7-1. MUA

STRESS CORROSION EVALUATION FORM

1. Part Number ____________________
2. Part Name ____________________
3. Next Assembly Number ____________________
4. Manufacturer ____________________
5. Material ____________________
6. Heat Treatment ____________________
7. Size and Form ____________________
8. Sustained Tensile Stresses-Magnitude and Direction
    a. Process Residual ____________________
    b. Assembly ____________________
    c. Design, Static ____________________
9. Special Processing ____________________
10. Weldments
    a. Alloy Form, Temper of Parent Metal ____________________
    b. Filler Alloy, if none, indicate ____________________
    c. Welding Process ____________________
    d. Weld Bead Removed - Yes ( ), No ( ) ____________________
    e. Post-Weld Thermal Treatment ____________________
    f. Post-Weld Stress Relief ____________________
11. Environment ____________________
12. Protective Finish ____________________
13. Function of Part ____________________
____
14. Effect of Failure ____________________
____
15. Evaluation of Stress Corrosion Susceptibility ____________________
____
16. Remarks: ____________________
____

Figure 7-2. Stress Corrosion Evaluation Form

POLYMERIC MATERIALS AND COMPOSITES USAGE LIST

SPACECRAFT ______________ SYSTEM/EXPERIMENT ______________ GSFC T/O ______________

DEVELOPER/CONTRACTOR______________ ADDRESS ______________

PREPARED BY ______________ PHONE ______________ DATE PREPARED______________

GSFC MATERIALS EVALUATOR ______________ PHONE ______________ DATE RECEIVED ______________ DATE EVALUATED ______________

Area, cm^2	Vol., cc	Wt., gm
1 0-1	A 0-1	a 0-1
2 2-100	B 2-50	b 2-50
3 101-1000	C 51-500	c 51-50(
4 >1000	D >500	d >500

ITEM NO.	MATERIAL IDENTIFICATION(2)	MIX FORMULA(3)	CURE(4)	AMOUNT CODE	EXPECTED ENVIRONMENT(5)	REASON FOR SELECTION(6)	OUTGASSIN VALUES TML	CV

NOTES

1. List all polymeric materials and composites applications utilized in the system except lubricants which should be listed on polymeric and composite materials usage list.

2. Give the name of the material, identifying number and manufacturer. Example: Epoxy, Epon 828, E. V. Roberts and Associates

3. Provide proportions and name of resin, hardener (catalyst), filler, etc. Example: 828/V140/Silflake 135 as 5/5/38 by weight

4. Provide cure cycle details. Example: 8 hrs. at room temperature + 2 hrs. at 150C

5. Provide the details of the environment that the material will experience as a finished S/C component, both in ground test and in space. List all materials with the same environment in a group. Example: T/V : -20C/+60C, 2 weeks, 10E-5 torr, ultraviolet radiation (UV)
   Storage: up to 1 year at room temperature
   Space: -10C/+20C, 2 years, 150 mile altitude, UV, electron, proton, atomic oxygen

6. Provide any special reason why the materials was selected. If for a particular property, please give the property.
   Example: Cost, availability, room temperature curing or low thermal expansion.

Figure 7-3. Polymeric Materials and Composites Usage List

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INORGANIC MATERIALS AND COMPOSITES USAGE LIST

SPACECRAFT ________________ SYSTEM/EXPERIMENT ________________ GSFC T/O ________________

DEVELOPER/CONTRACTOR________________ ADDRESS________________

PREPARED BY ________________ PHONE ________________ DATE PREPARED________________

GSFC MATERIALS EVALUATOR ________________ PHONE ________________ DATE RECEIVED ________________ DATE EVALUATED ________________

ITEM NO.	MATERIAL IDENTIFICATION(2)	CONDITION(3)	APPLICATION(4) OR OTHER SPEC. NO.	EXPECTED ENVIRONMENT(5)	S.C.C. TABLE NO.	MUA NO.	NDE METHOD

NOTES:

1. List all inorganic materials (metals, ceramics, glasses, liquids, and metal/ceramic composites) except bearing and lubrication materials that should be listed on Form 18-59C.
2. Give materials name, identifying number manufacturer.
   Example: a. Aluminum 6061-T6
   b. Electroless nickel plate, Enplate Ni 410, Enthone, Inc.
   c. Fused silica, Corning 7940, Corning Class Works
3. Give details of the finished condition of the material, heat treat designation (hardness or strength), surface finish and coating, cold worked state, welding, brazing, etc.
   Example: a. Heat treated to Rockwell C 60 hardness, gold electroplated, brazed.
   b. Surface coated with vapor deposited aluminum and magnesium fluoride
   c. Cold worked to full hare condition, TIG welded and electroless nickel plated.
4. Give details of where on the spacecraft the material will be used (component) and its function.
   Example: Electronics box structure in attitude control system, not hermetically sealed.
5. Give the details of the environment that the material will experience as a finished S/C component, both in ground test and in space. Exclude vibration environment. List all materials with the same environment in a group.
   Example: T/V: -20C/+60C, 2 weeks, 10E-5 torr, Ultraviolet radiation (UV)
   Storage: up to 1 year at room temperature
   Space: -10C/+20C, 2 years, 150 miles altitude, UV, electron, proton, Atomic Oxygen

Figure 7-4. Inorganic Materials and Composites Usage List

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LUBRICATION USAGE LIST

SPACECRAFT ____________ SYSTEM/EXPERIMENT ____________ GSFC T/O ____________

DEVELOPED/CONTRACTOR____________ ADDRESS____________

PREPARED BY ____________ PHONE ____________ DATE PREPARED____________

GSFC MATERIALS EVALUATOR ____________ PHONE ____________ DATE RECEIVED ____________ DATE EVALUATED ____________

ITEM NO.	COMPONENT TYPE, SIZE MATERIAL(1)	COMPONENT MANUFACTURER & MFR. IDENTIFICATION	PROPOSED LUBRICATION SYSTEM & AMT. OF LUBRICANT	TYPE & NO. OF WEAR CYCLES(2)	SPEED, TEMP., ATM. OF OPERATION(3)	TYPE OF LOADS & AMT.	OTHER DETAILS(5)

NOTES

(1) BB = ball bearing, SB = sleeve bearing, G = gear, SS = sliding surfaces, SEC = sliding electrical contacts. Give generic identification of materials used for the component, e.g., 440C steel, PTFE.

(2) CUR = continuous unidirectional rotation, CO = continuous oscillation, IR = intermittent rotation, IO = intermittent oscillation, SO = small oscillation, (<30°), LO = large oscillation (>30°), CS = continuous sliding, IS = intermittent sliding.
No. of wear cycles: A(1-10^2), B(10^2-10^4), C(10^4-10^6), D($>10^6$)

(3) Speed: RPM = revs./min., OPM = oscillations/min., VS = variable speed
CPM = cm/min. (sliding applications)
Temp. of operation, max. & min., °C
Atmosphere: vacuum, air, gas, sealed or unsealed & pressure

(4) Type of loads: A = axial, R = radial, T = tangential (gear load). Give amount of load.

(5) If BB, give type and material of ball cage and number of shields and specified ball groove and ball finishes. If G, give surface treatment and hardness. If SB, give dia. of bore and width. If torque available is limited, give approx. value.

Figure 7-5. Lubrication Usage List

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MATERIALS PROCESS UTILIZATION LIST

SPACECRAFT ______________________ SYSTEM/EXPERIMENT ______________________ GSFC T/O ____________

DEVELOPER/CONTRACTOR______________________ ADDRESS ______________________

PREPARED BY ______________________ PHONE ______________________ DATE PREPARED ____________

GSFC MATERIALS EVALUATOR ______________________ PHONE ____________ DATE RECEIVED ____________ DATE EVALUATED ____________

ITEM NO.	PROCESS TYPE[1]	CONTRACTOR SPEC. NO.[2]	MIL., ASTM., FED. OR OTHER SPEC. NO.	DESCRIPTION OF MAT'L PROCESSED[3]	SPACECRAFT/EXP. APPLICATION[4]

NOTES

(1) Give generic name of process, e.g., anodizing (sulfuric acid).

(2) If process if proprietary, please state so.

(3) Identify the type and condition of the material subjected to the process.
E.g., 6061-T6

(4) Identify the component or structure of which the materials are being processed.
E.g., Antenna dish

Figure 7-6. Materials Process Utilization List

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8 RESERVED

9 DESIGN VERIFICATION REQUIREMENTS

9.1 GENERAL REQUIREMENTS

A verification program shall be conducted to ensure that the systems meet the specified mission requirements. The program shall consist of functional demonstrations, analytical investigations, physical measurements and tests that simulate all expected environments. Adequate verification documentation shall be provided including a verification plan and matrix, environmental test matrix and verification procedures.

The Verification Program begins with functional testing of assemblies. It continues through functional and environmental testing supported by appropriate analysis, at the component, subsystem and instrument levels of assembly. The program concludes with end-to-end testing of the entire operational system, including the instrument and the appropriate Ground Data System elements.

The General Environmental Verification Specification (GEVS) for ELV Payloads, Subsystems, and Components shall be used as a baseline guide for developing the verification program. For a copy of the GEVS document, use the following hyperlink --- http://arioch.gsfc.nasa.gov/302/verifhp.htm. Alternative methods are acceptable provided that the net result demonstrates compliance with the intent of the requirements.

9.2 DOCUMENTATION REQUIREMENTS

9.2.1 System Performance Verification Plan

A System Performance Verification Plan shall be prepared and implemented (reference GEVS Section 2.1 and DID TBD). The plan shall define the tasks and methods required to verify the ability of the system to meet each specified mission requirement (structural, thermal, optical, electrical, guidance/control, RF/telemetry, science, mission operational, etc.), including records documenting compliance. Limitations in the ability to verify any performance requirement shall be addressed, including the addition of supplemental tests and/or analyses that will be performed and a risk assessment of the inability to fully verify the requirement.

The plan shall address how compliance with each specification requirement will be verified. If verification relies on the results of measurements and/or analyses performed at lower (or other) levels of assembly, this dependence shall be described.

For each analysis activity, the plan shall include objectives, a description of the mathematical model, assumptions on which the models will be based, required output, criteria for assessing the acceptability of the results, the interaction with related test activity, if any, and requirements for reports. Analysis results shall take into account tolerance build-ups in the parameters being used.

9.2.1.1 System Performance Verification Matrix

Documentation to demonstrate compliance with each system performance requirement shall be provided. A matrix, or equivalent system, shall be prepared and maintained that shows the flow-down of each performance requirement and the verification process. The matrix shall be iterated as verification is completed, kept current, and the status made available upon request. The matrix shall be included in the system review data packages showing the current verification status.

9.2.1.2 Performance Verification Procedures

For each performance verification test activity conducted at the component, subsystem, and instrument levels (or other appropriate levels) of assembly, procedures shall be prepared for verifying compliance with each system performance requirement. These procedures shall identify the verification article configuration and provide detailed instructions for accomplishing and documenting the verification activity. As-run copies of these procedures shall be archived for reference via a user-friendly retrieval process.

Verification test procedures shall contain details such as instrumentation monitoring, facility control sequences, test article functions, test parameters, pass/fail criteria, quality control checkpoints, data collection, and reporting requirements. The procedures shall also address safety and contamination control provisions.

9.2.1.3 Performance Verification Reports

Upon completion of each system performance verification activity, a report shall be prepared to summarize the findings and results. This report may be attached to the applicable as-run procedures or archived as a separate document. The combined matrix, as-run procedure records, and summary reports shall be developed and maintained "real-time" throughout the program; thereby demonstrating compliance with the applicable system performance requirements prior to delivery of hardware/ software to the next higher level of assembly.

9.2.2 Environmental Verification Plan

An Environmental Verification Plan (EVP) shall be prepared as part of the System Performance Verification Plan, or as a separate document, to prescribe the tests and analyses which will collectively demonstrate that the hardware and software comply with the environmental verification requirements. The EVP shall provide the overall approach to accomplishing the environmental verification program. For each test, it shall include the level of assembly, the configuration of the item, objectives, facilities, instrumentation, safety considerations, contamination control, test phases and profiles, necessary functional operations, personnel responsibilities, and requirement for procedures and reports. It shall also define a rationale for retest determination that does not invalidate previous verification activities. When appropriate, the interaction of the test and analysis activity shall be described.

Limitations in the environmental verification program that preclude the verification by test of any system requirement shall be documented. Alternative tests and analyses shall be evaluated and implemented as appropriate, and an assessment of the project risk shall be included in the System Performance Verification Plan.

The preliminary plan shall provide sufficient verification philosophy and detail to allow assessment of the program. For example, for the environmental test portion of the verification, it is not sufficient to state that the GEVS requirements will be met. A program philosophy must be included. Examples of program philosophy are:

- All components shall be subjected to random vibration.
- Random vibration shall be performed at the subsystem level of assembly rather than at the component level.
- All instruments shall be subjected to acoustics tests and 3-axis sine and random vibration.
- All components shall be subjected to EMC tests.
- All flight hardware shall see 8-thermal-vacuum cycles prior to integration on the spacecraft.

9.2.2.1 Environmental Verification Specification

As part of the System Performance Verification Plan, or as a separate document, an environmental verification specification shall be prepared that defines the specific environmental parameters that each system element is subjected to either by test or analysis in order to demonstrate its ability to meet the mission performance requirements. Such things as payload peculiarities and interaction with the launch vehicle shall be taken into account.

9.2.2.2 Environmental Test Matrix

As an adjunct to the system Environmental Verification Plan, a matrix, or equivalent system, shall be prepared and maintained that identifies all environmental tests that will be performed on each component, subsystem, and instrument clearly showing each environmental exposure and test article level of assembly. For an example of an environmental test matrix, refer to GEVS Figure 2.1-1. The purpose is to provide a ready reference to the contents of the environmental test program in order to prevent the deletion of a portion thereof without an alternative means of accomplishing the objectives. All flight hardware, spares and prototypes (when appropriate) shall be included in the matrix. The matrix shall be iterated as performance is completed, kept current, and the status made available upon request. The matrix shall be prepared in conjunction with the initial environmental verification plan and shall be updated as the project matures. This matrix may be combined with the Performance Verification Matrix on a common database. The matrix shall be included in the system review data packages showing the current status.

9.3 ELECTRICAL FUNCTIONAL TEST REQUIREMENTS

9.3.1 Electrical Interface Tests

As a part of the integration of a component or subsystem into the next higher level of assembly, electrical tests (reference GEVS Section 2.3.1) shall be performed to verify the interface configuration (power, grounds, commands, telemetry, signals, timing, etc,). Prior to mating with other hardware, electrical harnessing shall be tested to verify the wire routing, isolation, impedance, and overall workmanship. The following parameters shall be verified as a minimum:

- Accuracy (signals on correct pins and nowhere else)
- Inputs and outputs (unloaded and loaded)
- Specified range (high/low extremes as well as nominal)
- Range impacts (how range extremes of one signal affect related signals)

9.3.2 Aliveness Tests

An aliveness test may be performed to verify that the instrument and its major components are functioning.

9.3.3 Comprehensive Performance Tests (CPTs)

Appropriate CPTs shall be conducted at the subsystem and instrument levels of assembly (reference GEVS Section 2.3.2). The CPT shall be a detailed demonstration that the hardware and software meet their performance requirements within allowable tolerances. The CPT shall demonstrate the operation of redundant circuitry and satisfactory performance in all operational modes. CPTs shall demonstrate that, with the application of known stimuli and appropriate inputs, the test article will produce the expected responses and outputs within acceptable limits. The initial CPT shall serve as a baseline against which the results of all later CPT’s can be readily compared. CPT’s shall be identified in the System Performance Verification Plan. Specific times when CPTs will be performed shall be described in the Verification Plans.

9.3.4 Limited Performance Tests (LPTs)

Appropriate LPTs shall be conducted at the subsystem and instrument levels of assembly when CPTs are not warranted to demonstrate that the functional capability has not been degraded (reference GEVS Section 2.3.3). The LPT shall be a demonstration that the hardware and software meet their performance requirements within allowable tolerances. The LPT shall demonstrate the operation of redundant circuitry and satisfactory performance in selected operational modes. LPTs shall demonstrate that, with the application of known stimuli and appropriate inputs, the test article will produce the expected responses and outputs within acceptable limits. The initial LPT shall serve as a baseline against which the results of all later LPTs can be readily compared. Specific times when LPTs will be performed shall be described in the Verification Plans.

9.3.5 Support to End-to-End Performance Tests

The Contractor shall provide support to an end-to-end compatibility test which will be performed to demonstrate the ground system capability to communicate with the Observatory (up-link and down-link) via the ground to space network (reference GEVS Section 2.8). Simulated normal orbital mission scenarios encompassing launch, systems turn-on, housekeeping, command/control, and stabilization/pointing will be demonstrated, including the collecting, processing, and archiving of science data. Observatory immunity to erroneous commands, autonomous safe-hold, and simulated anomaly recovery operations will also be demonstrated.

9.3.6 Performance Operating Time and Failure-Free Performance Testing

At the conclusion of the performance verification program, the LDCM Instrument shall have demonstrated failure-free performance testing for a minimum of 300 hours of operation. Failure-free operation during the LDCM Instrument thermal-vacuum test exposure may be included.

9.4 STRUCTURAL AND MECHANICAL REQUIREMENTS

Compliance with the specified structural and mechanical requirements shall be demonstrated through a series of interdependent test and analysis activities (reference GEVS Section 2.4). These demonstrations shall verify design and specified factors of safety as well as ensure instrument interface compatibility, acceptable workmanship, and material integrity. Safety requirements shall be accomplished in conjunction with these demonstrations.

The design shall be sufficiently modularized to permit realistic environmental exposures at the component and subsystem level. Each subsystem shall be verified for each of the applicable requirements identified. It is the Contractor's responsibility to document a meaningful set of design verification activities that best demonstrates compliance with the systems performance requirements.

When planning the tests and analyses, the Contractor shall consider all expected environments, including the following:

- Structural loads (reference GEVS Section 2.4.1)
- Thermal balance (reference GEVS Section 2.6.3)
- Mass properties (reference GEVS Section 2.4.7)
- Mechanical mechanism functions (reference GEVS Section 2.4.5)
- Vibration (acoustics, 3-axis sine sweep and random) (reference GEVS Sections 2.4.2, 2.4.3)
- Mechanical shock (self induced, externally induced) (reference GEVS Section 2.4.4)
- Thermal vacuum (reference GEVS Section 2.6)
- Electromagnetic Compatibility (EMC) Requirements

9.5 ELECTROMAGNETIC COMPATIBILITY (EMC) REQUIREMENTS

The electromagnetic characteristics of hardware shall be designed in accordance with the systems performance requirements (reference GEVS Section 2.5) so that:

a. The instrument and its subsystems and components do not generate electromagnetic interference that could adversely affect its own subsystems and components or the safety and operation of the launch vehicle or the launch site.
b. The instrument and its subsystems and components are not susceptible to emissions that could adversely affect their safety and performance. This applies whether the emissions are self-generated or derived from other sources or whether they are intentional or unintentional.

10 WORKMANSHIP STANDARDS

10.1 GENERAL REQUIREMENTS

The Contractor shall plan and implement an Electronic Packaging and Processes Program to assure that all electronic packaging technologies, processes, and workmanship activities selected and applied meet mission objectives for quality and reliability.

10.2 APPLICABLE DOCUMENTS

The NASA preferred standards identified in the NASA technical standards program in the NASA Online Directives Information System (NODIS) shall be used. For copies of referenced documents, use the following hyperlink --- http://standards.nasa.gov/

- Conformal Coating and Staking: NASA-STD-8739.1, "Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies".
- Soldering – Flight, Surface Mount Technology: NASA-STD-8739.2, "Surface Mount Technology".
- Soldering – Flight, Manual (hand): NASA-STD-8739.3, "Soldered Electrical Connections".
- Soldering – Ground Systems: Association Connecting Electronics Industries (IPC)/Electronics Industry Alliance (EIA) J-STD-001C, "Requirements for Soldered Electrical and Electronic Assemblies".
- Electronic Assemblies – Ground Systems: IPC-A-610C, "Acceptability of Electronic Assemblies".
- Crimping, Wiring, and Harnessing: NASA-STD-8739.4, "Crimping, Interconnecting Cables, Harnesses, and Wiring".
- Fiber Optics: NASA-STD-8739.5, "Fiber Optic Terminations, Cable Assemblies, and Installation".
- ESD Control: ANSI/ESD S20.20, "Protection of Electrical and Electronic Parts, Assemblies and Equipment" (excluding electrically initiated explosive devices).
- Printed Wiring Board (PWB) Design:
  - IPC-2221, "Generic Standard on Printed Board Design".
  - IPC-2222, "Sectional Design Standard for Rigid Organic Printed Boards".
  - IPC-2223, "Sectional Design Standard for Flexible Printed Boards".
- PWB Manufacture:
  - IPC A-600F, "Acceptability of Printed Boards".
  - IPC-6011, "Generic Performance Specification for Printed Boards".

- IPC-6012, "Qualification and Performance Specification for Rigid Printed Boards"
  - Flight Applications – Supplemented with: GSFC S312-P-003, Procurement Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses (copy in Appendix D)
- IPC-6013, "Qualification and Performance Specification for Flexible Printed Boards".

Alternate workmanship standards may be used when approved by the GSFC LDCM Project. The Contractor shall submit the alternate standard (identifying the differences between the alternate standard and the required standard) for GSFC LDCM Project approval prior to use.

10.3 DESIGN

10.3.1 Printed Wiring Boards (PWB)

The PWB manufacturing and acceptance requirements identified in this chapter are based on using PWBs designed in accordance with the PWB design standards referenced above. Space flight PWB designs shall not include features that prevent the finished boards from complying with the Class 3 requirements of the appropriate manufacturing standard (e.g., specified plating thickness, internal annular ring dimensions, etc.).

10.3.2 Ground Data Systems (GDS)

GDS assemblies, that interface directly with space flight hardware, shall be designed and fabricated using space flight parts, materials, and processes for any portion of the assemblies (connectors, test cables, etc.) that:

- mate with the flight hardware
- will reside with the space flight hardware in environmental chambers or other test facilities that simulate a space flight environment

10.4 WORKMANSHIP REQUIREMENTS

10.4.1 Training and Certification

All personnel working on flight hardware (and applicable GDS) shall be certified as having completed the required training, appropriate to their involvement, as defined in the above standards. This includes, but is not limited to, the aforementioned workmanship and ESD standards.

10.4.2 Flight Workmanship

PWBs shall be manufactured in accordance with the Class 3 requirements in the above referenced IPC PWB manufacturing standards and GSFC/S312-P-003, "Procurement Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses". PWB test coupons shall be provided to the GSFC Materials Engineering Branch (MEB) or a GSFC/MEB approved laboratory for evaluation in accordance with contract requirements. Approval shall be obtained prior to population of flight PWBs. Test coupons and test reports evaluated by a GSFC/MEB approved laboratory are not required for delivery to GSFC/MEB. However, the coupons/reports shall be retained and included as part of the documentation/data deliverables package to the LDCM project.

10.4.3 GDS (non-flight) Workmanship

PWBs shall be manufactured in accordance with the Class 2 requirements in the above referenced IPC PWB manufacturing standards. Assemblies shall be fabricated using the Class 2 requirements of J-STD-001C, IPC-A-610C, and ANSI/ESD S20.20. If any conflicts between J-STD-001C and IPC-A-610C are encountered, the requirements in J-STD-001C shall take precedence.

10.5 ESD REQUIREMENTS

The Contractor shall document and implement an ESD Control Program, compliant with ANSI/ESD S20.20, Protection of Electrical and Electronic Parts, Assemblies and Equipment (excluding electrically initiated explosive devices. The program shall protect the most sensitive parts involved in the project and ensure that all manufacturing, inspection, testing, and other processes will not compromise mission objectives for quality and reliability due to ESD events. At a minimum, the ESD Control Program shall address training, protected work area procedures and verification schedules, packaging, facility maintenance, handling, storage, and shipping.

All personnel who manufacture, inspect, test, otherwise process electronic hardware, or require unescorted access into ESD protected areas shall be certified as having completed the required training, appropriate to their involvement, as defined in ANSI/ESD S20 prior to handling any electronic hardware.

Electronic hardware shall be manufactured, inspected, tested, or otherwise processed only at designated ESD protective work areas. These work areas shall be verified on a regular schedule as identified in the ESD Control Program.

Electronic hardware shall be properly packaged in ESD protective packaging at all times when not actively being manufactured, inspected, tested, or otherwise processed. Materials selected for packaging or protecting ESD sensitive devices shall not leach chemicals, leave residues, or otherwise contaminate parts or assemblies.

10.6 NEW/ADVANCED PACKAGING TECHNOLOGIES

New and/or advanced packaging technologies (multi-chip modules (MCMs), stacked memories, chip on board, etc.) that have not previously been used in space flight applications shall be reviewed and approved through the Parts Control Board (PCB) as defined in Chapter 6. When appropriate, a detailed Technology Validation Assessment Plan (TVAP) may be developed for each new technology. A TVAP identifies the evaluations and data necessary for acceptance of the new/advanced technology for reliable use and conformance to project requirements.

New/advanced technologies will be part of the Parts Identification List (PIL) and Project Approved Parts List (PAPL) defined in Section 6.3 of this document.

11 RISK MANAGEMENT REQUIREMENTS

11.1 GENERAL REQUIREMENTS

The Contractor shall plan and implement a Continuous Risk Management (CRM) program applicable to the development of all software and hardware products and processes (flight and ground.

The Contractor shall:

a. Identify, document, evaluate, classify, and prioritize reliability risks before they become problems
b. Develop and implement risk mitigation strategies, actions, and tasks and assign appropriate resources
c. Track risk being mitigated; capture risk attributes and mitigation information by collecting data; establish performance metrics; and examine trends, deviations, and anomalies
d. Control risks by performing: risk close-out, re-planning, contingency planning, or continued tracking and execution of the current plan
e. Communicate and document (via the risk recording, reporting, and monitoring system) risk information to ensure it is conveyed between all levels of the project
f. Report on outstanding risk items at all management and design reviews.

11.2 RISK MANAGEMENT PLAN

The Contractor shall prepare a Risk Management Plan applicable to the system level for which they are responsible. The plan shall be available at the Contractor's facility for LDCM Project review. The plan shall include risks associated with hardware (technical challenges, new technology qualification, etc.), software, COTS, system safety, performance, and programmatic risks (cost and schedule). The plan shall identify which tools and techniques will be used to manage risks. The risk areas that are identified shall be addressed at peer reviews (component, subsystem) and technical reviews (instrument). Although not all risks will be fully mitigated, all risks shall be addressed with mitigation and acceptance strategies agreed upon at appropriate reviews.

12 CONTAMINATION CONTROL REQUIREMENTS

12.1 GENERAL REQUIREMENTS

The Contractor shall plan and implement a contamination control program for LDCM hardware. Specific cleanliness requirements shall be established and the approaches to meet the requirements shall be delineated in a Contamination Control Plan (CCP) deliverable to the GSFC LDCM Project for concurrence.

Contamination includes all materials of molecular and particulate nature whose presence degrades hardware performance. The source of the contaminant materials may be the hardware itself, the test facilities, and the environments to which the hardware is exposed.

12.2 CONTAMINATION CONTROL PLAN

A CCP shall be prepared that describes the procedures that will be followed to control contamination. The CCP shall define a contamination allowance for performance degradation of contamination sensitive hardware such that, even in the degraded state, the hardware will meet its mission objectives. The CCP shall establish the implementation and describe the methods that will be used to measure and maintain the levels of cleanliness required during each of the various phases of the hardware's lifetime. The contamination potential of material and equipment used in cleaning, handling, packaging, tent enclosures, shipping containers, bagging (e.g., anti-static film materials), and purging shall be described in detail for each subsystem or component at each phase of assembly, integration, test, and launch. In general, all mission hardware should be compatible with the most contamination-sensitive components.

12.3 MATERIAL OUTGASSING

All materials shall be screened in accordance with NASA Reference Publication 1124, Outgassing Data for Selecting Spacecraft Materials. Individual material outgassing data shall be established based on each component's operating conditions. Established material outgassing data shall be verified and shall be provided to the GSFC LDCM Project for review.

12.4 THERMAL VACUUM BAKEOUT

Thermal vacuum bakeouts of all hardware shall be performed as required to protect contamination-sensitive components. The parameters of such bakeouts (e.g., temperature, duration, outgassing requirements, and pressure) must be individualized depending on materials used, the fabrication environment, and the established contamination allowance. Thermal vacuum bakeout results shall be verified and shall be provided to the GSFC LDCM Project for review.

A quartz crystal microbalance (QCM), or temperature controlled quartz crystal microbalance (TQCM), and cold finger shall be incorporated during all thermal vacuum bakeouts at the instrument level. These devices shall provide additional information to enable a determination of the duration and effectiveness of the thermal vacuum bakeout as well as compliance with the CCP.

Appendix A REFERENCE DOCUMENTS LIST

DOCUMENT	DOCUMENT TITLE
ANSI/ESD S20.20	ESD Association Standard for the Development of an Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (excluding electrically initiated explosive devices)
ANSI/IPC-D-275	Design Standard for Rigid Printed Boards and Rigid Printed Board Assemblies
ANSI/ISO/ASQ Q9001-2000	American National Standard Quality Management System Requirements
ANSI/ISO/ASQC Q9001-1994	American National Standard Quality Systems - Model for Quality Assurance in Design, Development, Production, Installation, and Servicing
ANSI/ISO/ASQC-Q10013	Guidelines for Developing Quality Manuals
ANSI/ISO-17025	General Requirements for the Competence of Testing and Calibration Laboratories
ASTM E-595	Total Mass Loss (TML) and Collected Volatile Condensable Materials (CVCM) from Outgassing in a Vacuum Environment
EWR 127-1	Eastern and Western Range Policies and Procedures
GEVS	General Environmental Verification Specification for STS & ELV Payloads, Subsystems, and Components, rev A, dated June 1996
GSFC PPL-21	GSFC Preferred Parts List
EEE-INST-002	Instructions for EEE Parts Selection, Screening, Qualification, and Derating

GSFC S312-P-003	Procurement Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses
IEEE STD 730	IEEE Standard for Software Quality Assurance Plans
IPC-A-600	Acceptability of Printed Wiring Boards
IPC-A-610C	Acceptability of Electronic Assemblies
IPC/EIA J-STD-001C	Requirements for Soldered Electrical and Electronic Assemblies
IPC-2221	Generic Standard on Printed Board Design
IPC-2222	Sectional Design Standard for Rigid Organic Printed Boards
IPC-2223	Sectional Design Standard for Flexible Printed Boards
IPC-6011	Generic Performance Specifications for Printed Boards
IPC-6012	Qualification and Performance Specification for Rigid Printed Boards
IPC-6013	Qualification and Performance Specification for Flexible Printed Boards
JSC 26943	Guidelines for the Preparation of Payload Flight Safety Data Packages and Hazard Reports
KHB 1700.7C	Space Transportation System Payload Ground Safety Handbook
KHB 1710.2D	Kennedy Space Center Safety Practices Handbook
MIL-HDBK-217	Reliability Prediction of Electronic Equipment
MIL-STD 1629A	Procedures for Performing a Failure Mode Effects and Criticality Analysis
MIL-STD-756B	Reliability Modeling and Prediction
MSFC CR 5320.9	Payload and Experiment Failure Mode Effects Analysis and Critical Items List Ground Rules

MSFC-HDBK-527	Material Selection List for Space Hardware Systems
MSFC-SPEC-522	Design Criteria for Controlling Stress Corrosion Cracking
NASA RP 1124	Outgassing Data for Selecting Spacecraft Materials
NASA RP-1161	Evaluation of Multi-layer Printed Wiring Boards by Metallographic Techniques
NASA-STD-6001	Flammability, Odor, Off-Gassing and Compatibility Requirement and Test Procedures for Materials in Environments that Support Combustion
NASA-STD-8719.8	Expendable Launch Vehicle Payload Safety Review Process Standard
NASA-STD-8719.13A	NASA Software Safety Standard
NASA-STD-8729.1	Planning, Developing, and Managing an Effective Reliability and Maintainability (R&M) Program
NASA-STD-8739.1	Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies
NASA-STD-8739.2	Workmanship Standard for Surface Mount Technology
NASA-STD-8739.3	Workmanship Standard for Soldered Electrical Connections
NASA-STD-8739.4	Workmanship Standard for Crimping, Interconnecting Cables, Harnesses and Wiring
NASA-STD-8739.5	Workmanship Standard for Fiber Optic Terminations, Cable Assemblies and Installation
NHB 1700.7	Safety Policy and Requirements for Payloads using the Space Transportation System
NPD 8700.1	NASA Policy for Safety and Mission Success
NPD 8710.3	NASA Policy for Limiting Orbital Debris Generation

NPD 8720.1	NASA Reliability and Maintainability (R&M) Program Policy
NPG 7120.5	Program and Project Management Process and Requirements
NPSL	NASA Parts Selection List
NSS 1740.13	Software Safety Standard
NSS 1740.14	Guidelines and Assessment Procedures for Limiting Orbital Debris
NUREG-0492	Fault Tree Handbook
RADC-TR-85-229	Reliability Predictions for Spacecraft
S-311-M-70	Specification for Destructive Physical Analysis
541-PG-8072.1.2	Goddard Space Flight Center Fastener Integrity Requirements (formerly GSFC S-313-100)